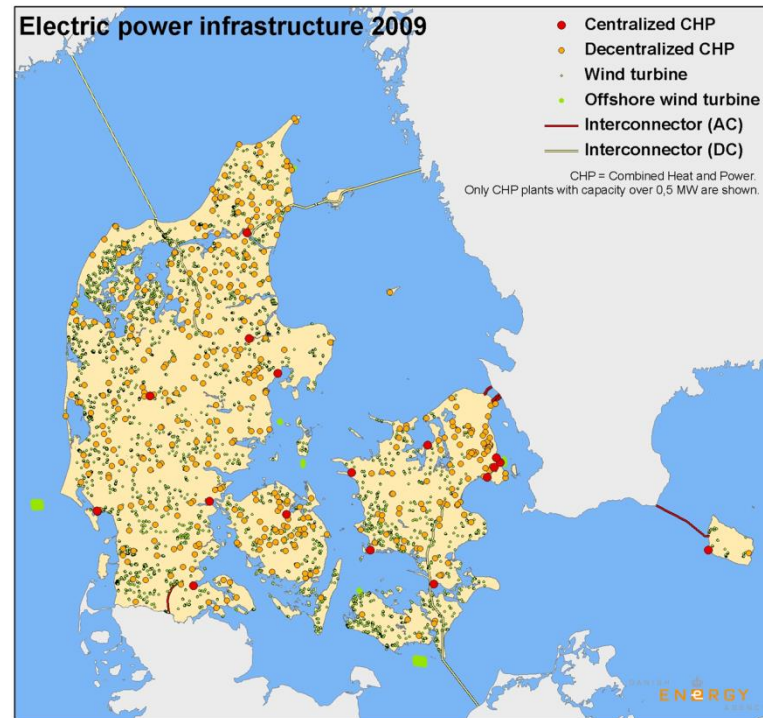
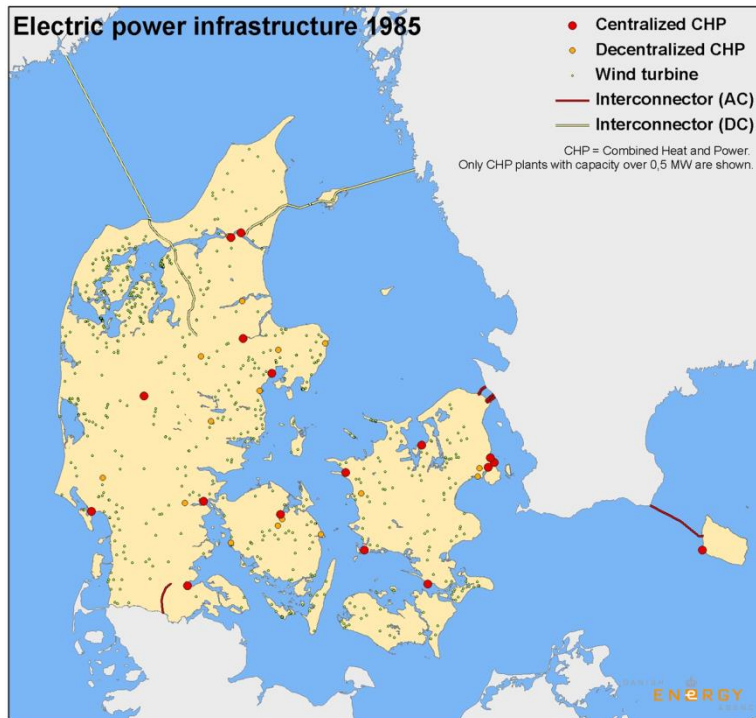


# **DISTRIBUTED CHP PLANTS IN RENEWABLE ENERGY SYSTEMS**

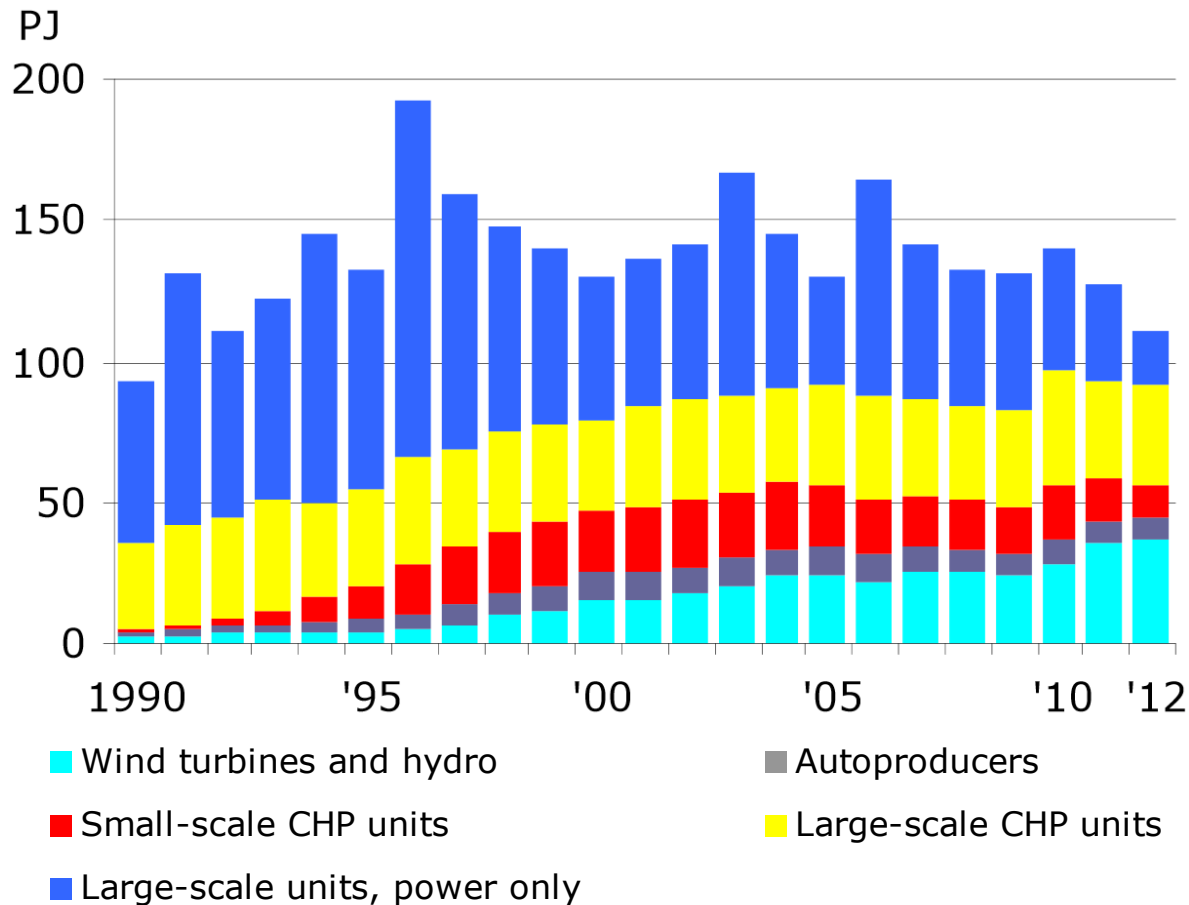
**PETER SORKNÆS, PHD-FELLOW  
AALBORG UNIVERSITY**



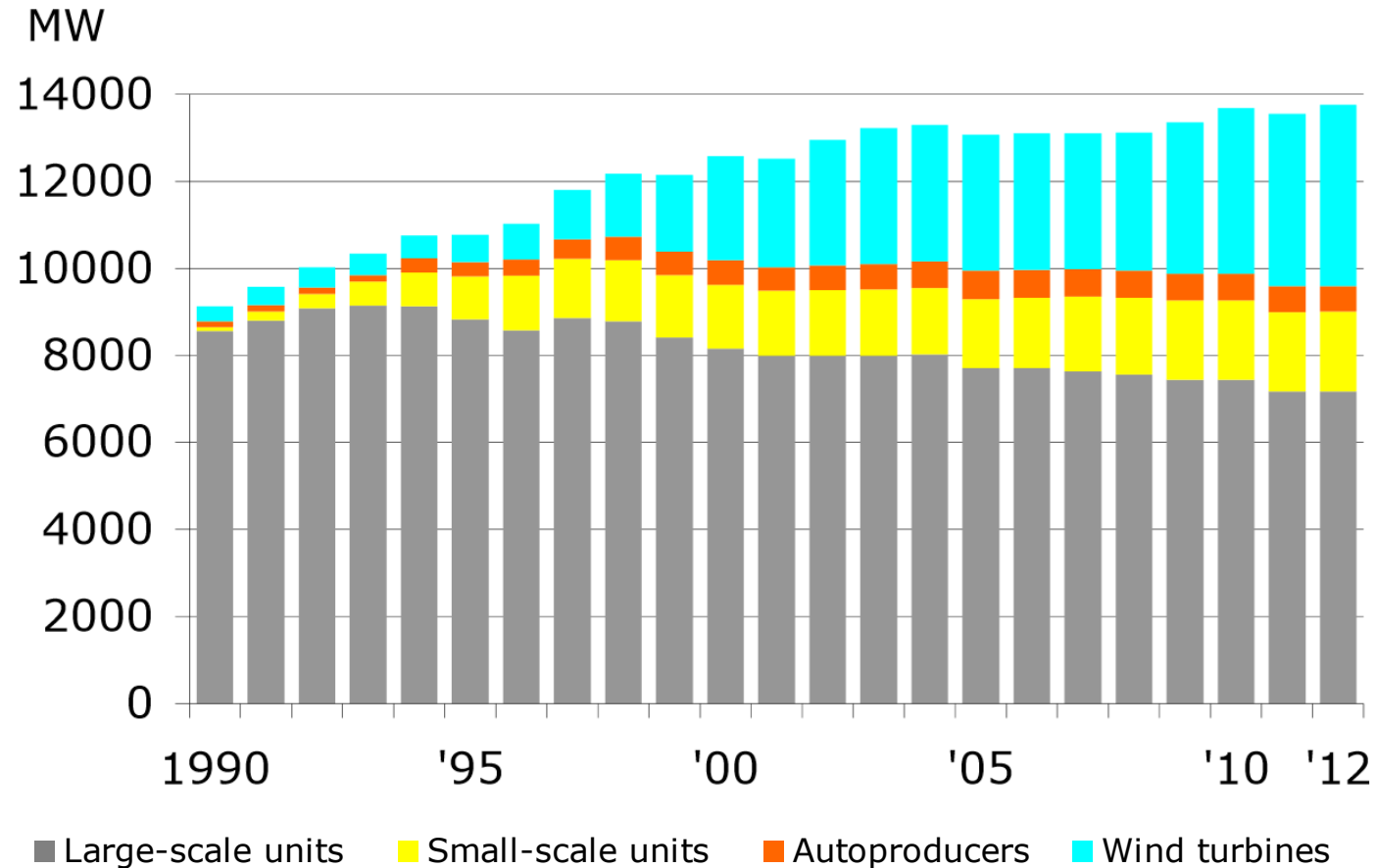
# The development of the Danish electricity system



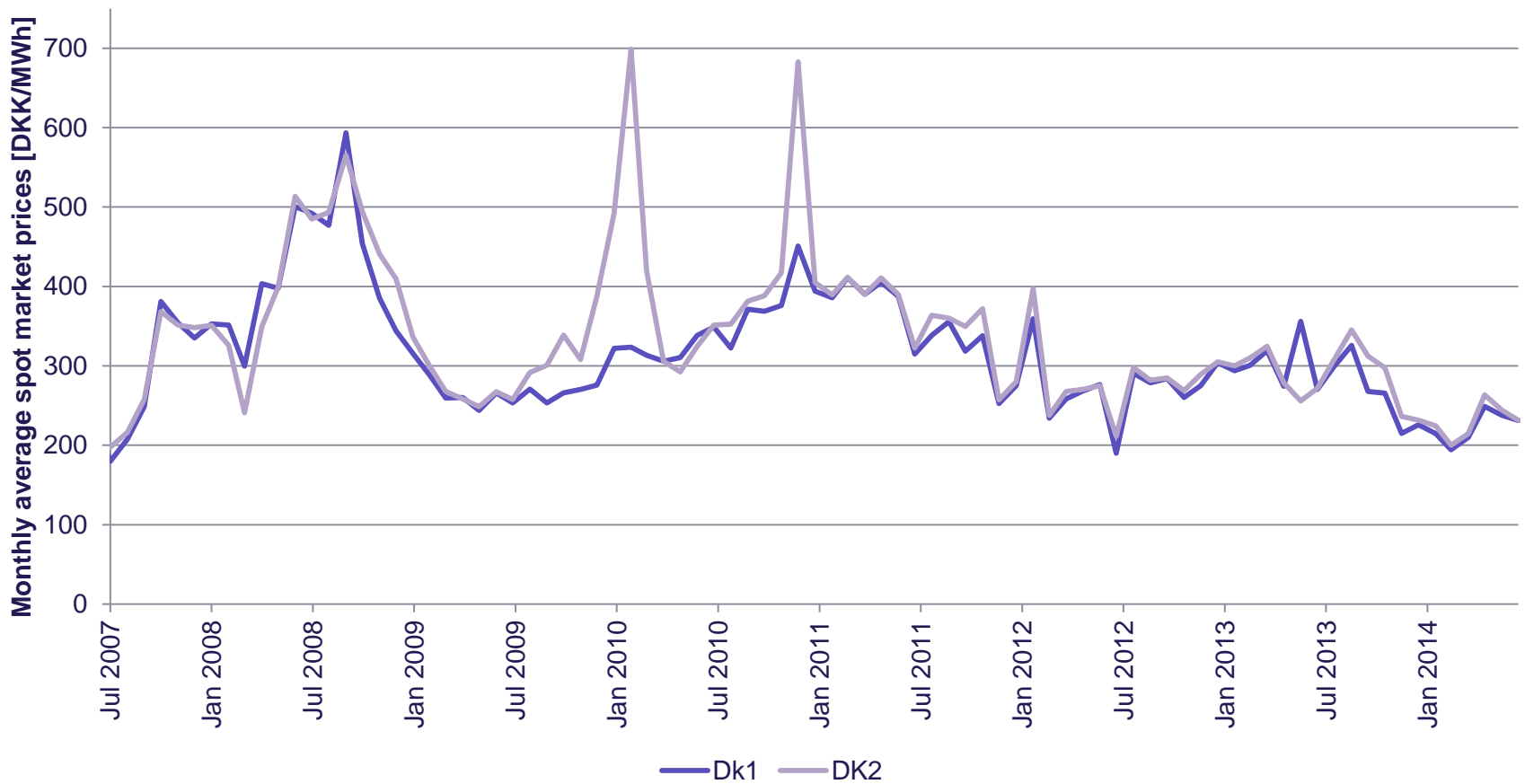
# Electricity production by type of producer



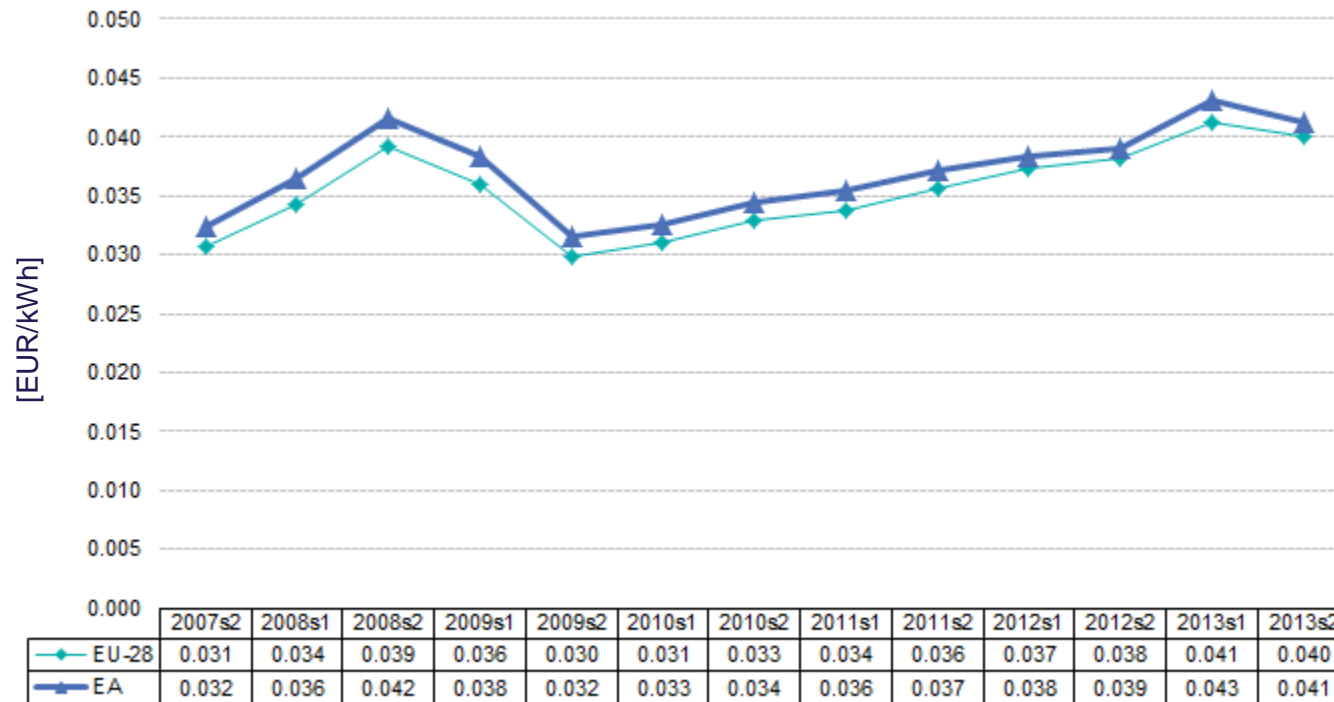
# Electricity capacity by type of producer



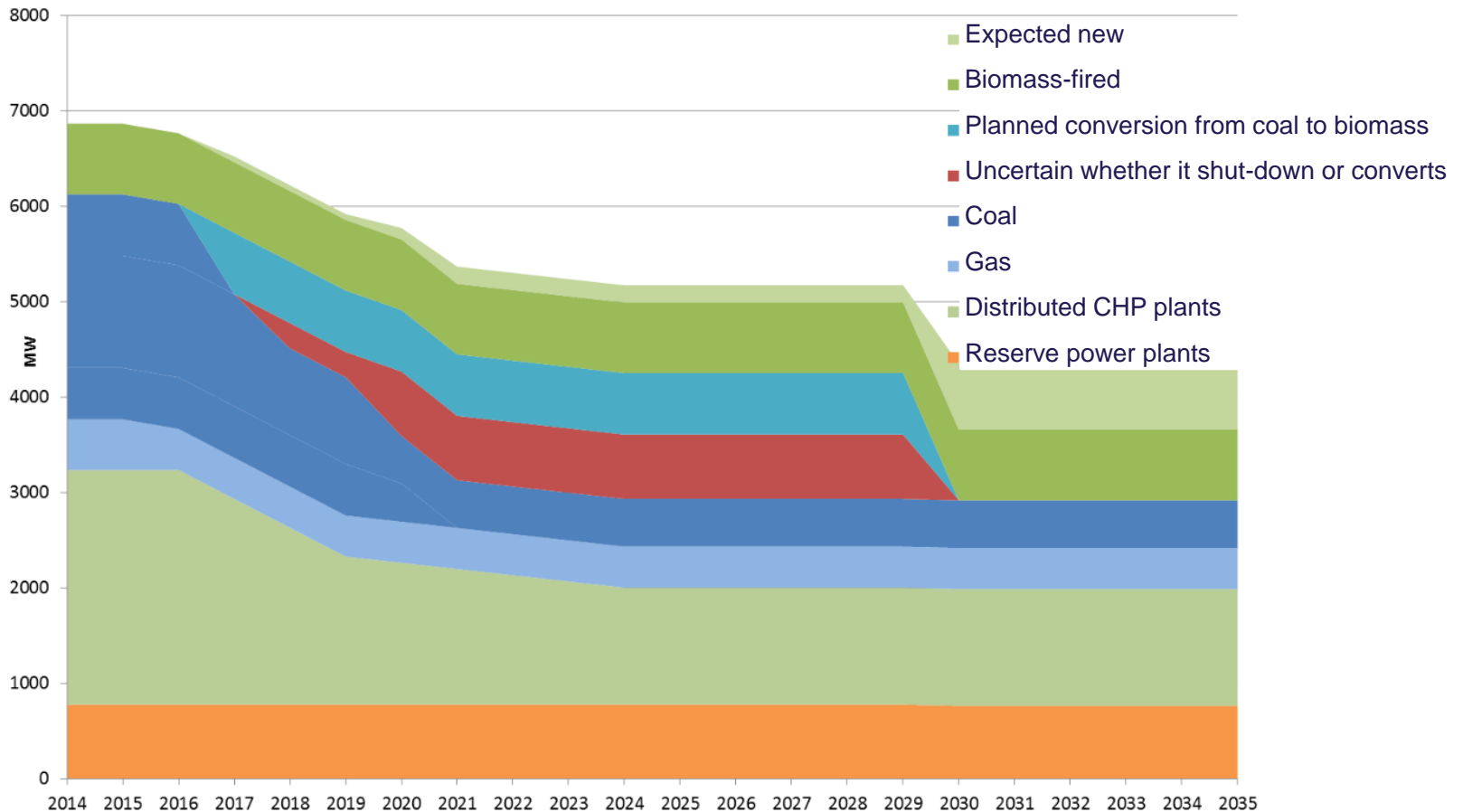
# Development in spot market prices in Western Denmark (DK1) and Eastern Denmark (DK2)



# Development of natural gas prices for industrial consumers, EU-28 and Euro Area (EA)



# Energinet.dk's expectations to the development of power plant capacity in Denmark



Wind power is expected to increase from 4,800 MW in 2014 to 8,194 MW in 2035

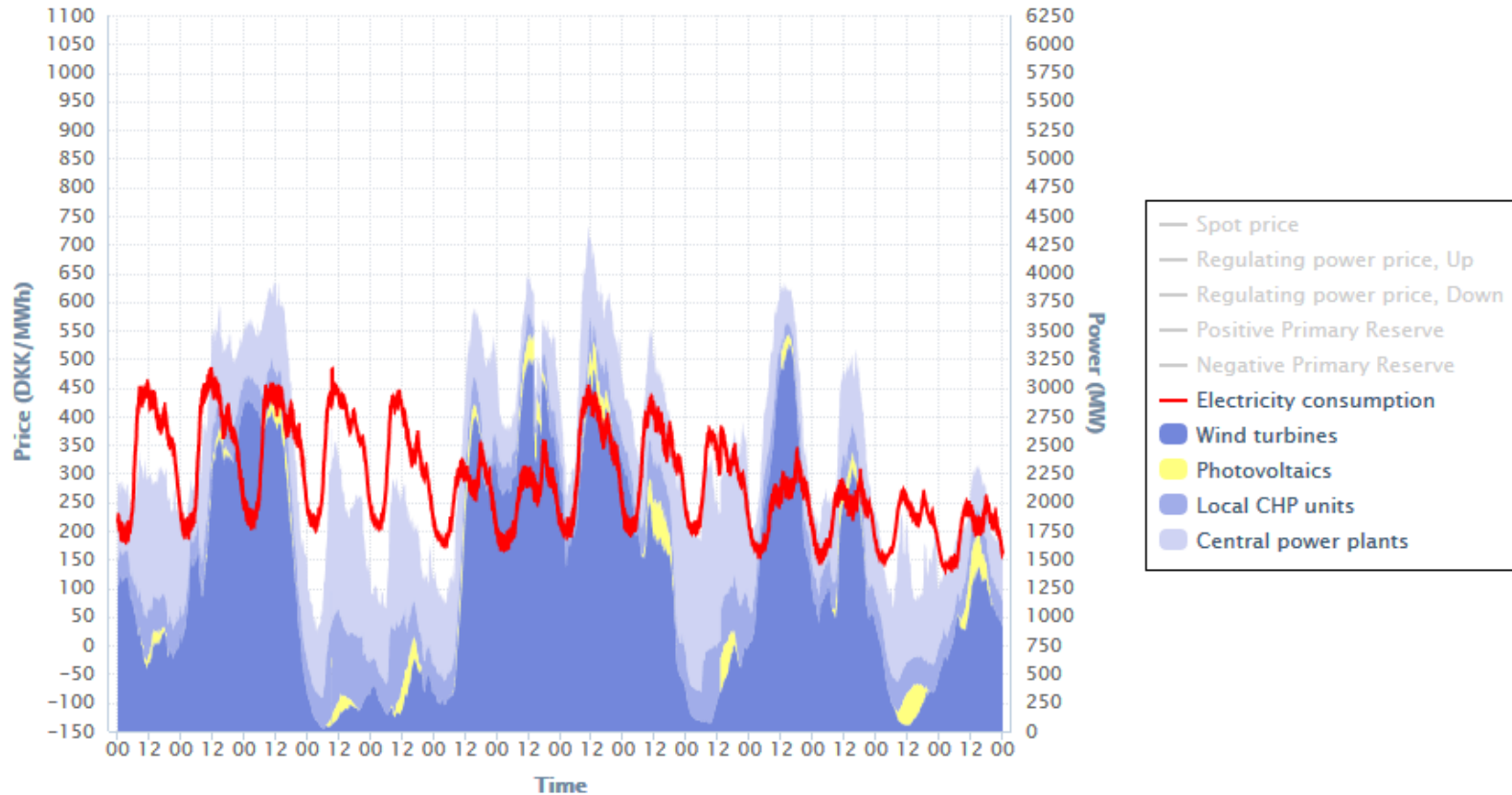
# Is distributed CHP plants still needed in a future energy system?

- *“In the CEESA scenarios, the smart energy system integration is crucial. Electricity smart grids are only one part of this system. The scenarios rely on a holistic smart energy system including the use of:  
1) Heat storages and district heating with CHP plants and large heat pumps.[...]”*<sup>1</sup>
- *”Increased wind power is not an obstacle for continued expansion of district heating and CHP. It is important, however, that CHP should be produced more flexible. Flexibility can be increased through increased use of thermal storage, electric boilers and heat pumps.”*<sup>2</sup>



# Electricity production and consumption

West Denmark, Monday, 2014-4-7 to Sunday, 2014-4-20

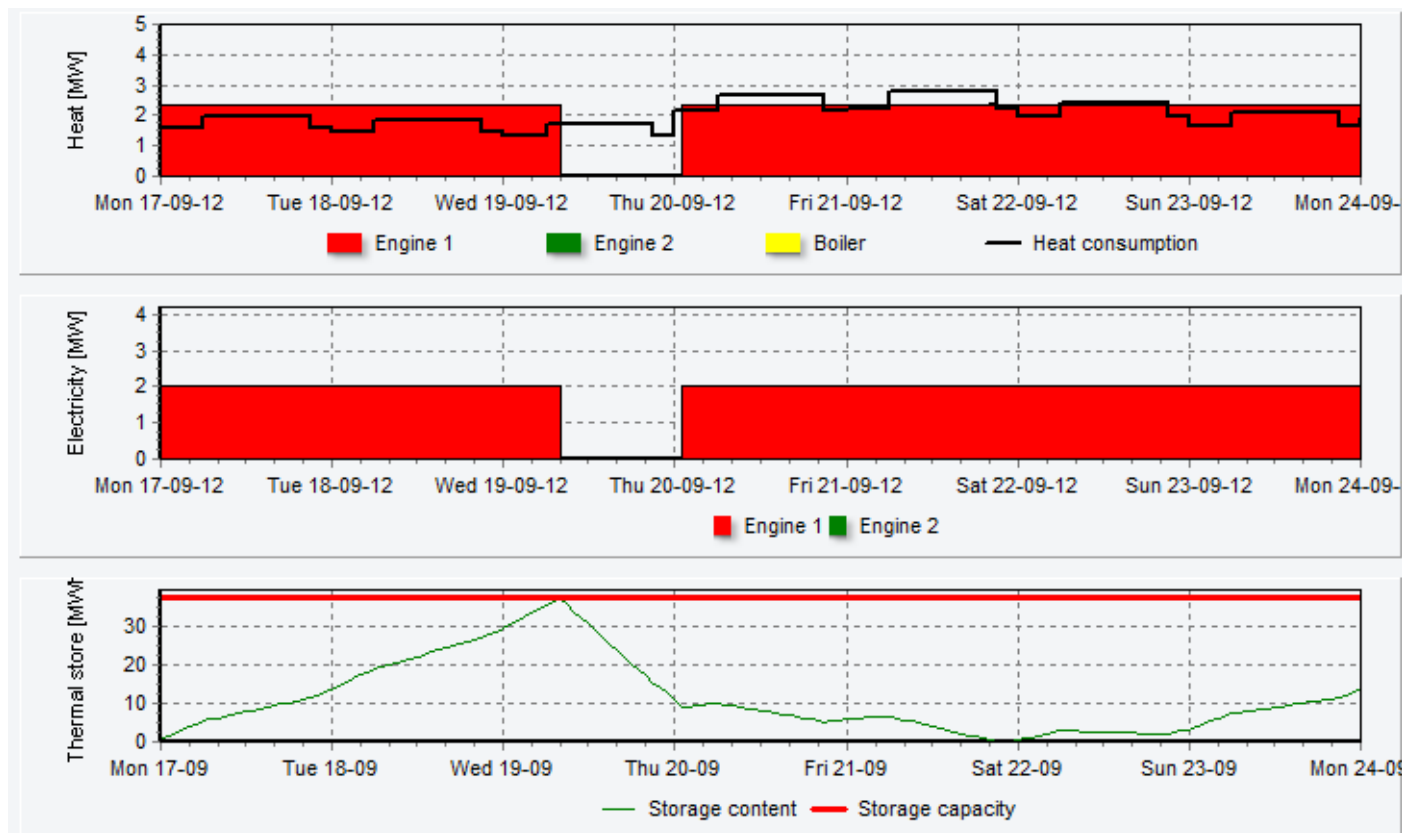


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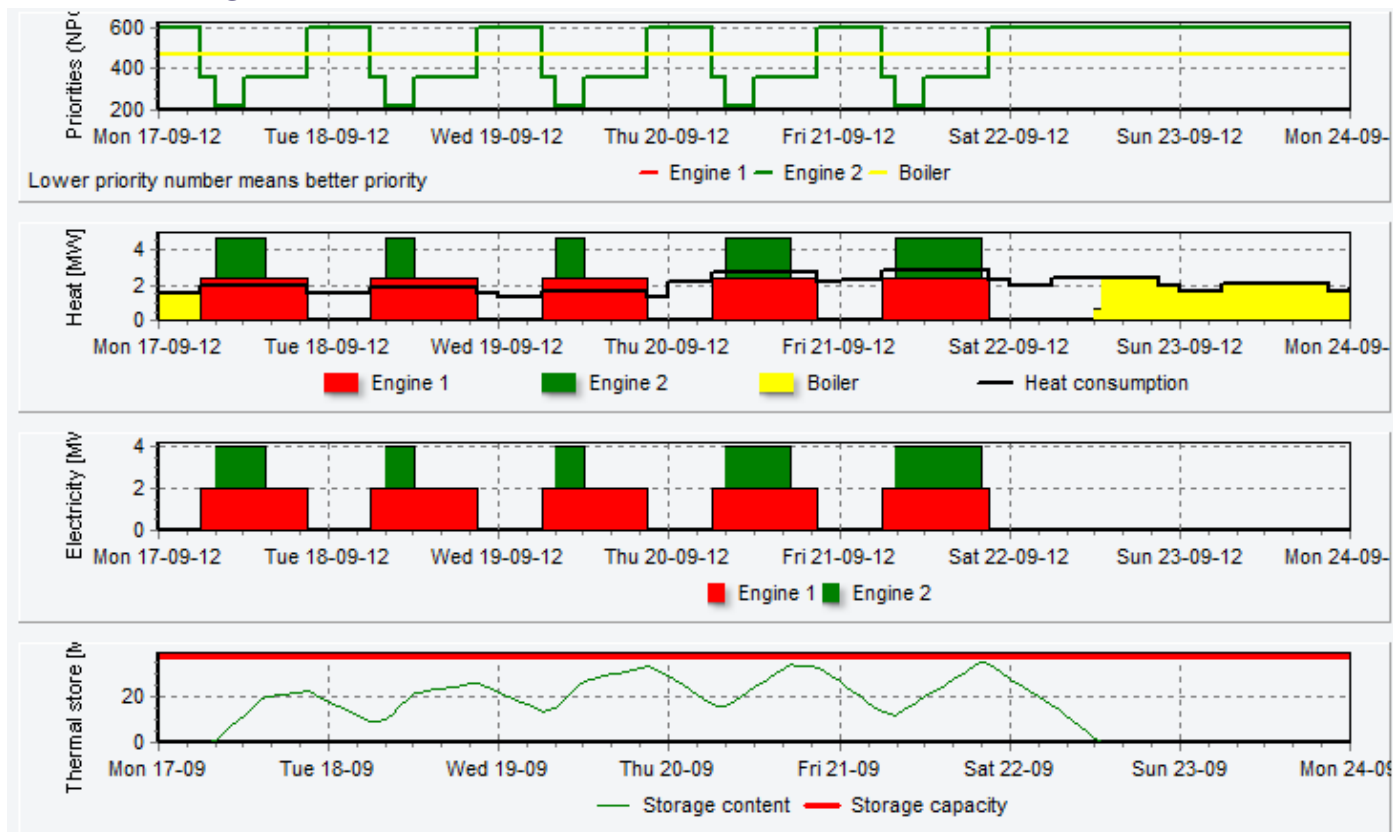
# Development of distributed CHPs interaction with the electricity system

- **Stage 1** - Electricity is sold at a fixed price, in which the price does not vary in time.



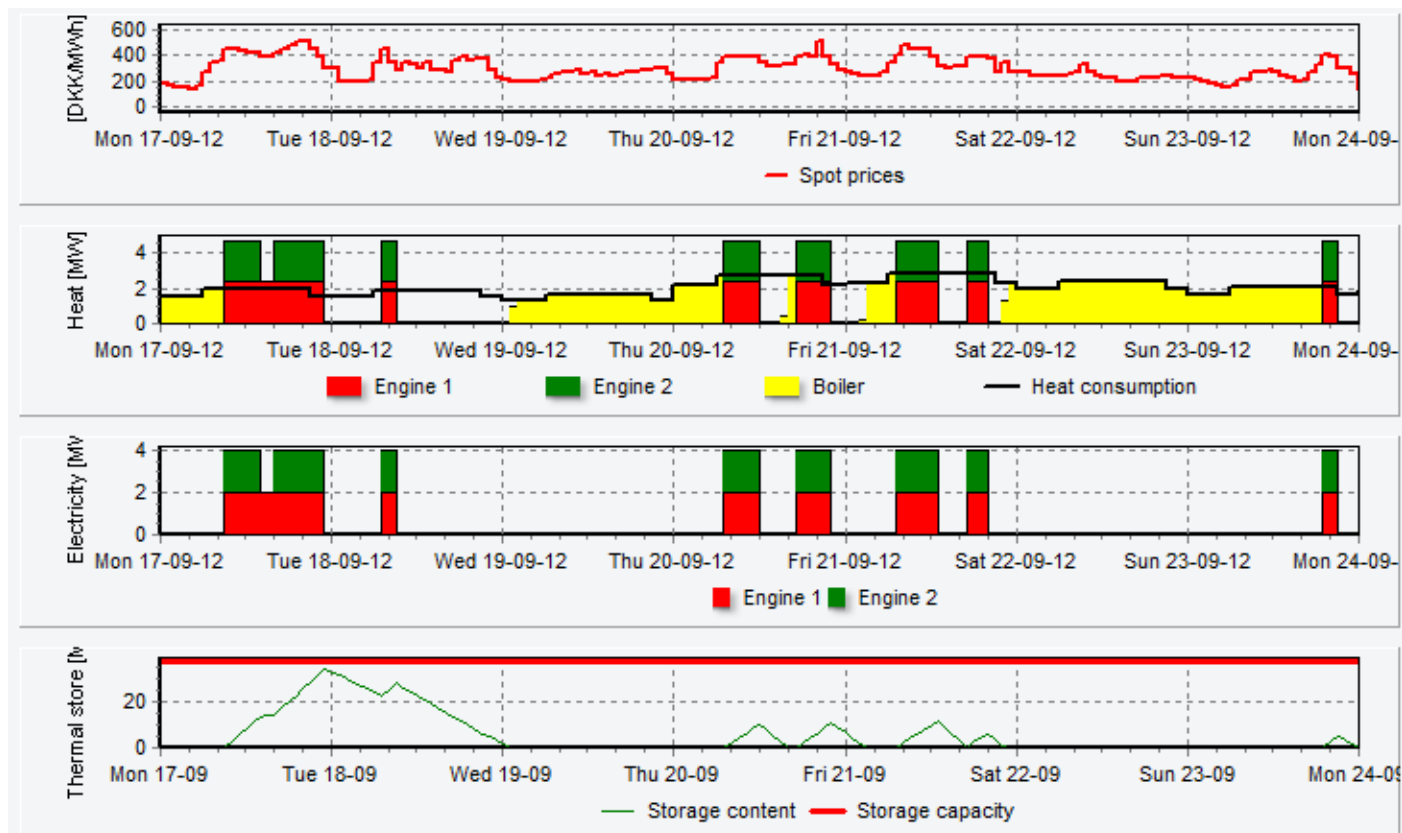
# Development of distributed CHPs interaction with the electricity system

- **Stage 2** - Electricity is sold according to the triple tariff (or similar), in which the price varies in accordance with typical variations in the demand. The variation was known in advance and did not change if, for example, the demand changes.



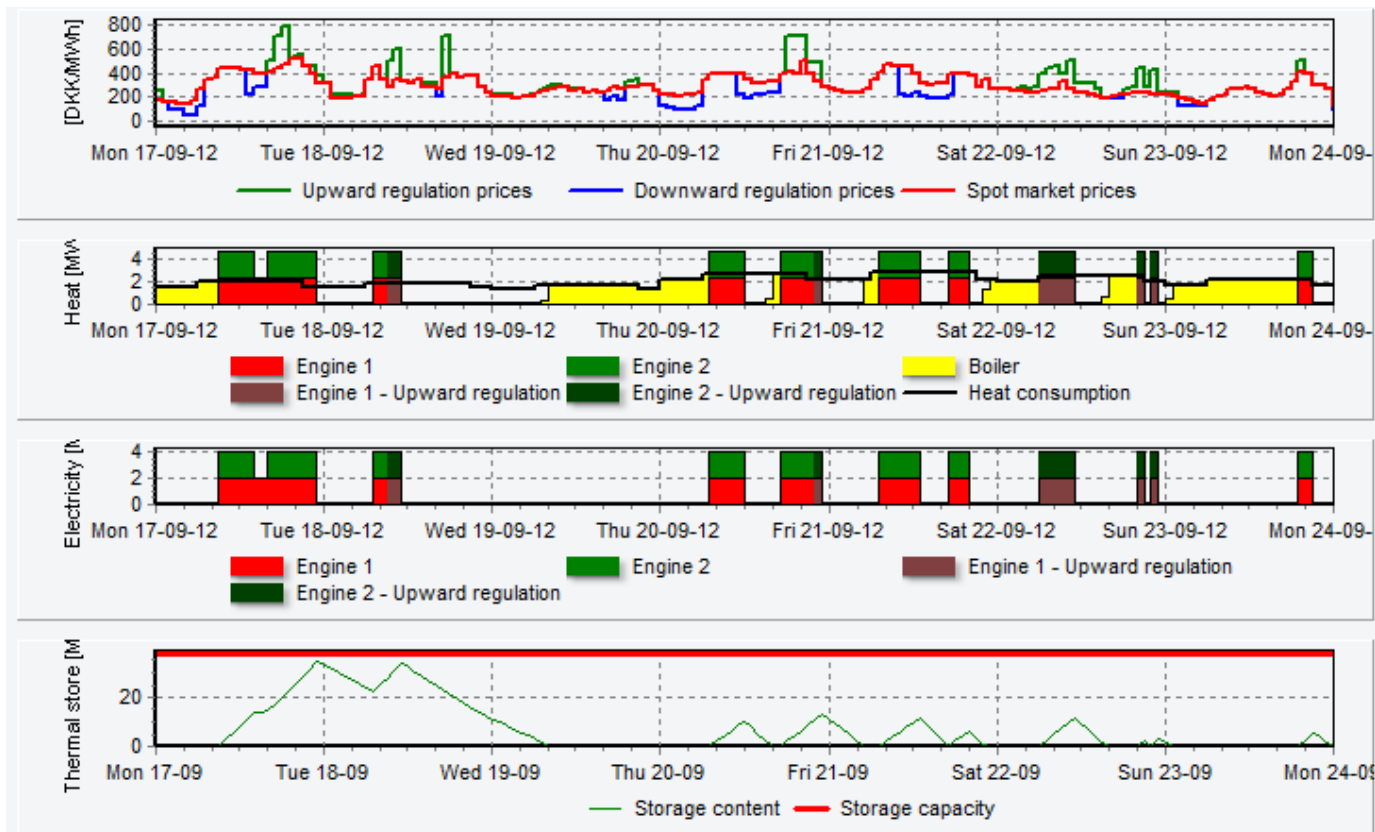
# Development of distributed CHPs interaction with the electricity system

- **Stage 3** - Electricity is sold on electricity wholesale market, in which the prices vary from hour to hour. The prices are negotiated in advance.



# Development of distributed CHPs interaction with the electricity system

- **Stage 4** - Full electricity market integration. Participation on both the spot market and the electricity system balancing markets.

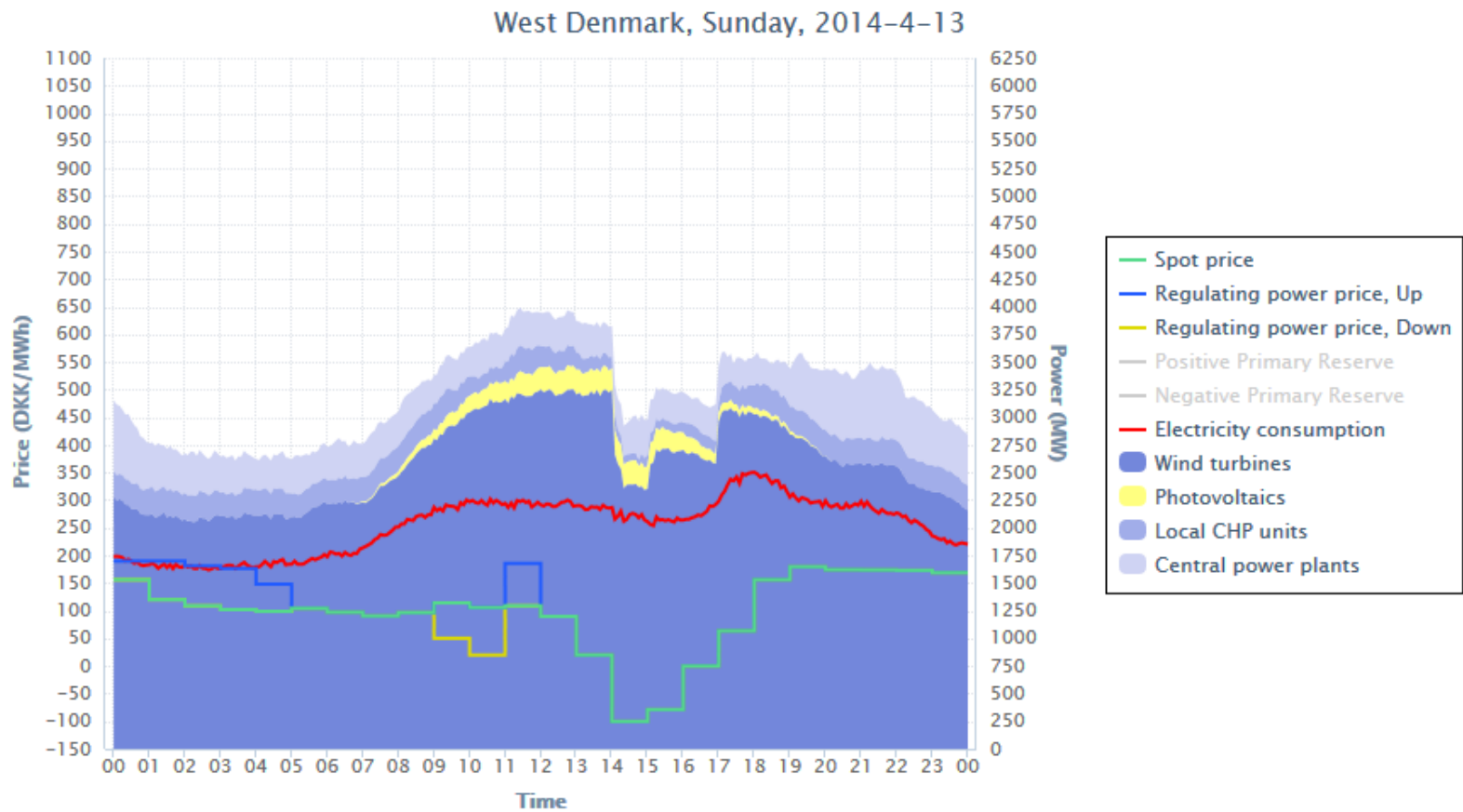


# Other development of distributed CHP plants that affect the electricity system participation

- Solar thermal production is increasing.
  - In 2007, the total installed solar collector field area in district heating systems in Denmark was less than 50,000 m<sup>2</sup>. In 2013, this had increased to nearly 400,000 m<sup>2</sup>.
- Day-ahead gas market is becoming increasingly used.
- Increasing capacity of electricity consuming heat production units, such as electric boilers and heat pumps.
  - Makes the low electricity prices relevant for the distributed plants.



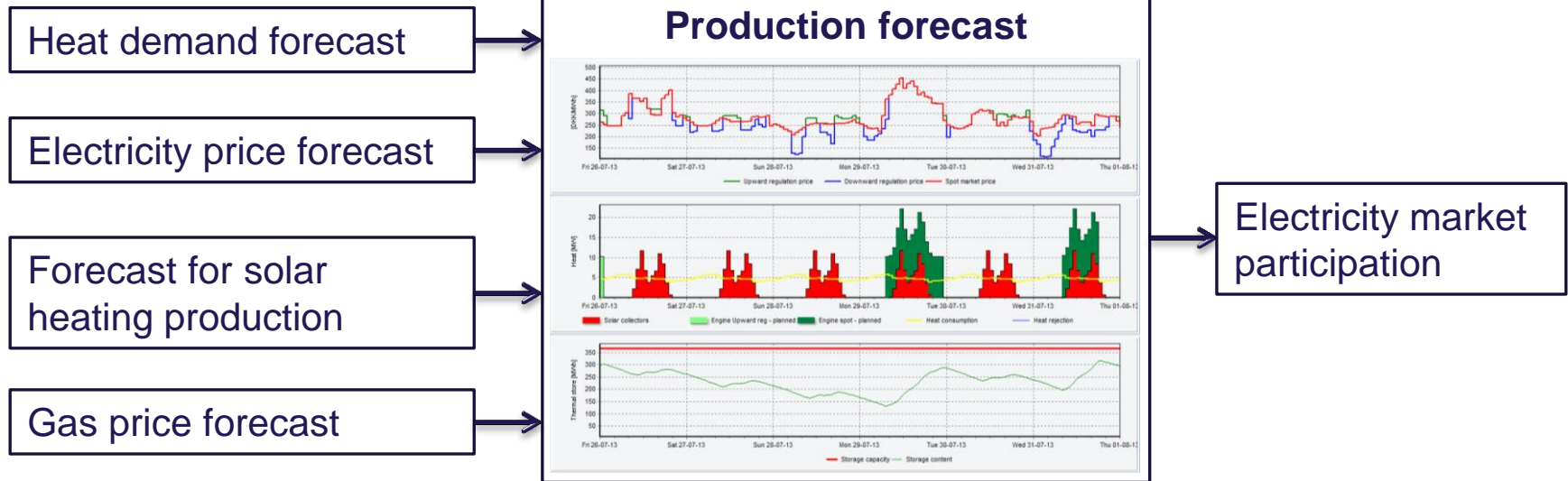
# Electricity prices, production and consumption



This graph is hosted and maintained by EMD International A/S



# Forecasts used in daily operation





# Final remarks

- Simulations indicate that plants can improve the economic feasibility of their CHP units by participating in the electricity balancing tasks, compared with only wholesale market participation.
  - However, due to the increasing importance of forecasts, the gate-closure for trading affects the potential gains from participation.
- Faster starting engines can for some balancing markets improve the feasibility of participation for distributed CHP plants.
- It is not certain that this increased feasibility is sufficient to keep the distributed CHP capacity operational.

